

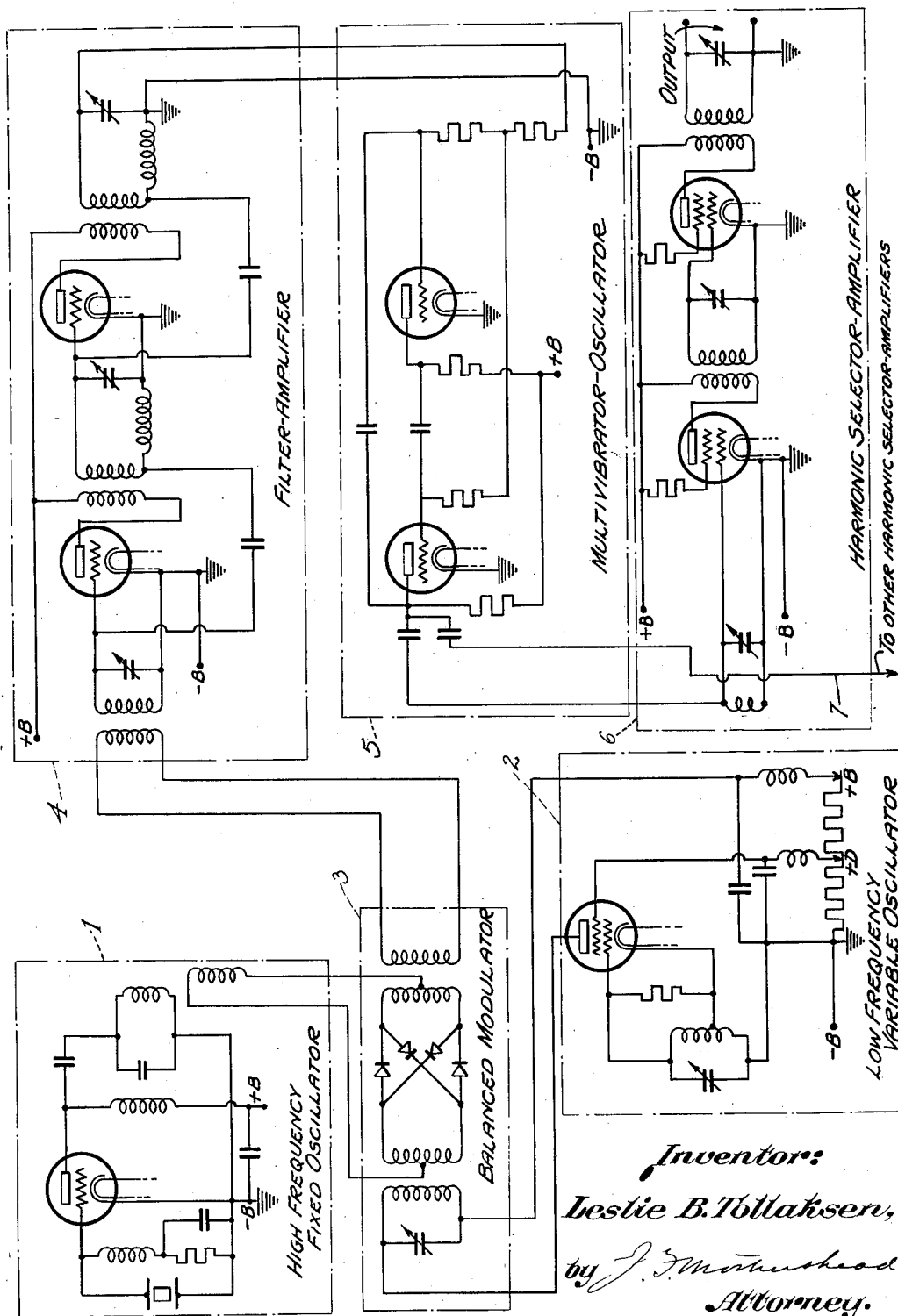
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CONTINUOUSLY VARIABLE CRYSTAL-STABILIZED OSCILLATOR

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CONTINUOUSLY VARIABLE CRYSTAL-STABILIZED OSCILLATOR

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(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the Act of April 30, 1928 (ch. 460, 45 Stat. L. 467).

This invention relates to oscillation generators and more particularly to a continuously variable crystal stabilized oscillator in which the stability characteristics of a quartz crystal controlled oscillation generator are combined with the controllable variability of frequency characteristics of a vacuum tube oscillation generator in such a manner as to obtain a useful output which has both these characteristics over an extremely wide range of frequency.

The easiest and most common method of obtaining an extremely stable frequency is by the use of a quartz crystal controlled oscillation generator. To make any appreciable change in frequency of the crystal oscillation generator, however, requires the change of the crystal and so, to obtain a continuous variable oscillation generator from such a device alone would require a vast number of crystals. Quartz crystal oscillation generators find their best application at the higher frequencies while vacuum tube oscillators find their best application at the lower frequencies.

The present invention is concerned with an arrangement which furnishes a useful frequency which is adapted to be varied quite readily over a wide range of frequencies and yet is extremely stable.

It has heretofore been proposed to combine a high frequency quartz crystal oscillation generator with a low frequency vacuum tube variable frequency oscillation generator, in a balanced modulator, and by the use of some suitable filters select one side band for use. It was found, however, that this side band could only be used for a variation in frequency of about 5%, for any greater variation would reduce the stabilizing influence of the quartz crystal to such an extent that a vacuum tube oscillation generator could be easily built with this reduced stability and with a much wider frequency range.

If, however, the above mentioned side band be used within this restricted range to control the harmonic output of some such oscillation generator as what is commonly termed a "multi-vibrator" by virtue of the latter's characteristic behavior of synchronizing or locking in step with a suitable voltage and frequency injected at one of the multi-vibrator harmonics, then one

has available a very large number of frequencies evenly spaced throughout the frequency spectrum and all capable of being varied simultaneously in frequency about 5%.

The spacing determined by the fundamental of the multi-vibrator can be adjusted so that it is equal to the smallest variation in frequency to be used and thus a continuous coverage is obtainable. One or more suitable harmonic selector amplifiers can be used then to silence the particular multi-vibrator harmonic, or harmonics, in order to obtain the desired output frequency.

By suitably choosing the various elements almost any desired frequency range and stability may be obtained with the above described arrangement wherein the present invention is described generally.

One specific embodiment of the basic idea of the present invention is shown schematically in the accompanying drawing.

In the drawing, 1 is a quartz crystal oscillator. A more or less conventional oscillator circuit has been shown, but it is to be understood that any desired oscillator of high stability may be used in lieu thereof.

For the purpose of this description it may be assumed, for example, that the oscillator 1 generates a frequency of 1070 kc. and has a stability of 0.014% over any ambient temperature conditions between -30°C . and $+60^{\circ}\text{C}$.

2 represents any type of vacuum tube oscillation generator whose frequency may be varied at will, and for purposes of illustration is herein shown as being of the electron coupled vacuum tube oscillator type with a frequency range, for example, of 20 kc. to 70 kc. It is to be understood, however, that an oscillation generator of the type disclosed in the article by J. B. Dow in the Proceedings of Radio Engineers, vol. 19, p. 2095 (Dec. 1931), or any other type of reasonably stable adjustable frequency oscillator may be used. The oscillations from oscillation generators 1 and 2 are fed to the input circuits of the balanced modulator 3 which may be any type of balanced modulator or "mixer" and is herein illustrated as a copper oxide type. The oscillations from oscillation generators 1 and 2 are combined in the balanced modulator 3 to produce the fundamental carrier and two side bands in the usual manner. The output of the balanced modulator 3 is coupled to the input of the filter amplifier 4 which as shown in the drawing consist of two triode stages of amplification, each stage of which is neutralized. Obviously, how-

ever, instead of triodes, tetrodes, or pentodes may be used and the neutralization dispensed with.

In the tuned circuits of the filter amplifier 4 the carrier and the upper side band is discriminated against and the lower side band is selected and amplified after which it is passed to the multi-vibrator oscillator circuit 5. With the high frequency oscillator 1 generating a frequency of 1070 kc., and with the lower frequency oscillation generator 2 adjusted for the generation of 20 kc. the side band energy taken from the balanced modulator 3 would be at 1050 kc. and 1090 kc., respectively. Assuming the stability of the low frequency oscillator 2 to be of the order of 0.1% and with the stability of the crystal oscillator 1 to be of the order of 0.014%, the stability of the lower side band, for instance, would be

$$\frac{1070}{1050} (0.014\%) + \frac{20}{1050} (0.1\%) = 0.01615\%$$

which is a stability very closely approximating that of the crystal itself, and it would be even better if the low frequency variable oscillation generator were at the other extreme such as 70 kc. Up to this point in the circuit, however, there is available about a 5% variation in frequency, for if the frequency range of the variable frequency oscillation generator is increased very much with respect to the frequency of the quartz crystal oscillation generator the resulting stability will decrease rapidly.

To overcome this difficulty and provide stability, after the filter amplifiers 4 has suppressed the upper side band, for example, and the fundamental carrier remnants, the lower side band is fed into some oscillator which is rich in harmonics such, for example, as the one illustrated at 5 which is commonly called a multi-vibrator oscillator. To carry out the example, assume that the fundamental frequency of this multi-vibrator oscillator is 100 kc. and all harmonics are present, although this latter condition is not necessary. The lower side band previously mentioned is injected and synchronizes or locks in step with the tenth harmonic of the multi-vibrator oscillator and the two frequencies stay locked in step as the lower side band is varied between 0% and 5% by a suitable adjustment of the frequency controls of the low frequency variable oscillation generator 2. In like manner the fundamental and all harmonics of the multi-vibrator oscillator 5 change in frequency and the same percentages are rigidly controlled by the injected lower side band frequency, which in turn is controlled by the frequency adjustments of the low frequency variable oscillation generator 2.

One or more of these harmonics of the multi-vibrator oscillator 5 thus controlled may be selected out from the rest and amplified by the harmonic selector amplifier illustrated at 6 in the drawing. Any type of a controllable multi-vibrator oscillator that is rich in harmonics may be used in lieu of the circuit shown at 5 as, for instance, those mentioned in the article by J. K. Clapp, entitled Universal frequency standardization from a single frequency standard, published in J. O. S. A. & R. S. I., vol. 15, July 1927, or the article by H. Abraham and E. Bloch, Mesure en Valeur Absolue des periodes des Oscillations Electriques de Haute frequence, appearing in Ann. de physique, 12, p. 237; 1919.

Also, any type of harmonic selector amplifier 75 may be used which has good selectivity in lieu

of the one illustrated at 6 comprising screen grid tubes and high Q resonant circuits.

Because a 5% variation in frequency is equal to the 100 kc. separation in harmonics in the example given at about 2000 kc. the lower frequency limit of the example would be stated as 2000 kc. Other ranges can be set at will by using other values than those stated in the example.

In certain installations where it is desired to derive more than one frequency from those present in the output harmonics of the multi-vibrator oscillator 5 other harmonic selectors such as 7 may be coupled to the output of the multi-vibrator for that purpose. After selection and amplification of the desired harmonic in the harmonic selector amplifier 6 the selected frequency is transferred to the output circuit 8 of any of the harmonic selector amplifiers. The output frequency present at 8 is then essentially as stable as the frequency generated by the quartz crystal oscillation generator, and this frequency can be made continuously variable over as wide a range as desired while still retaining high inherent stability.

While I have disclosed a preferred embodiment of my invention in detail, it will be apparent that various changes might be made within the contemplated scope of my invention, and I, therefore, do not desire to be limited to the specific details described, except insofar as is necessitated by the prior art and by the appended claims.

What I claim is:

1. An apparatus for generating substantially constant frequency oscillations at any desired frequency within a wide band comprising in combination a relatively high frequency mechanically controlled oscillator having a high degree of frequency stability, a second oscillator for generating a relatively low frequency compared to the frequency generated by said mechanically controlled oscillator, means for inter-modulating the oscillations from said oscillators, means for selecting an inter-modulation product, a multi-vibrator oscillator for producing oscillations having a great number of harmonically related components, means for impressing said selected inter-modulation product on said multi-vibrator oscillator for controlling the frequency of its harmonically related components whereby the frequency components derived from the output of said multi-vibrator vary in frequency in accordance with the frequency variation of the inter-modulation product impressed thereon, means for varying the frequency of said low frequency oscillator sufficiently to vary the output frequency components of said multi-vibrator oscillator from one value to another value such that the frequency of a selected harmonic at one setting of said low frequency oscillator is equal to the frequency of an adjacent harmonic at another setting in at least a portion of the frequency spectrum of the multi-vibrator oscillator, whereby any desired frequency of oscillation within a wide band may be obtained by appropriate variation of the frequency of said low frequency oscillator and the selection of a concomitantly varied appropriate harmonic of said multi-vibrator, providing a variable frequency of oscillation having the frequency stability of the order of a mechanically controlled oscillator.

2. A system in accordance with claim 1 in which the mechanically controlled oscillator is of the piezo electric crystal control type and the second oscillator is of the continuously variable frequency electron coupled type.

3. The method of utilizing a piezo electric crystal having certain inherent frequency characteristics to control the frequency stability of a continuously variable oscillation generator which
5 comprises generating a frequency dependent solely upon the characteristics of said crystal, generating a second frequency not dependent upon the characteristics of said crystal and inter-modulating said two frequencies, selecting the lower
10 side band of said inter-modulated frequencies and suppressing the upper side bands and fundamental, generating a plurality of frequencies harmonically related to a frequency of the selected side band controlling the frequency of said plurality of harmonically related frequencies in accordance with the inter-modulation product of
15 said first two frequencies, varying the value of said second frequency sufficiently to cause a frequency shift of the frequencies harmonically related by an appreciable percentage such that the frequency of a selected harmonic at one setting of said variable oscillation generator is equal to
5 the frequency of an adjacent harmonic at another setting and selecting from said plurality of harmonically related frequencies a frequency having a predetermined desired relationship to the side band selected whereby any desired frequency of
10 oscillation having the frequency stability of the order of said piezo-electric crystal may be obtained by appropriate variation in the value of the second frequency and an appropriate selection of a harmonic from said plurality of harmonically related frequencies.
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